HIGH PRESSURE TUBE CLEANING APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to cleaning equipment for tubes and piping and, in particular, to high-pressure water spray systems for cleaning the bores of tubes mounted in a variety of equipment, such as heat exchangers, falling pressure evaporators and the like.

Industrial piping systems of all types frequently require cleaning. A problem especially common to heat exchangers and evaporators is that over time the bore and exterior walls of the heat exchange tubes develop corrosion, scale and other undesired residue. The buildup of residue decreases and/or generally adversely effects the heat transfer efficiencies. Operating costs for fuel, in turn, increase.

Periodic maintenance is thus required to clean the tubes. Frequently the equipment must be taken off-line during maintenance. Such maintenance can be performed by plant personnel or outside contractors who are specially trained and use special purpose equipment to perform such tasks. It is desirable that any down time be minimized. The task is typically performed manually and is therefore costly and time consuming, especially for large heating and cooling plants.

A variety of techniques and types of equipment have been developed to clean the interior and exterior surfaces of pipes and particularly heat transfer tubes. Soot blowing and chemical shocking are two techniques. Another technique is to individually direct equipment into each tube to mechanically dislodge the residue from the tube walls. Some of the latter equipment uses rigid lances that either rotate and/or have rotating blades. US patent 5,579,726 discloses a lance-based assembly that directs streams of high-

pressure water to effect the cleaning. The latter system supports a rotating and axially directed lance from a frame that can be aligned to each tube.

High-pressure spray systems are also known that direct streams of water from a spray hose into each tube. Jetting Systems & Accessories, Inc. sells one such system under the brand name "FLEX LANCER". Another system is sold by Gardner Denver Water Jetting Systems, Inc., Houston, TX under the name "V" Drum Rotary Line Cleaner. The latter system provides a high-pressure hose and spray nozzle that are rotated and axially directed under power. Hose movement is directed with a hand-operated air controller and a pinch roller assembly that controls axial hose movement. Rotational movement is controlled via a separate motor. The hose is collected and dispensed from a rotating V-shaped spool or drum. Although offering advantages, the efficiency of the latter system is severely restricted by vibrations that occur due to unbalanced conditions that can occur at the equipment during typical use. Extreme vibrations have particularly been experienced at speeds approaching 60 rpm, which severely limits the utility of the equipment.

The present invention was developed to provide a more efficient high-pressure spray system. The assembly provides a hose mounted spray head that can be operated at rotational speeds in the range of 60 rpm to 850 rpm. Axial speeds in the ranges of 1 foot per minute to 80 feet per minute are also possible. At a nominal rotary speed of 300 rpm and an axial speed of 60 feet per minute the assembly is able to clean a typical 36-foot tube in one-fourth the time as the foregoing equipment.

The assembly is constructed to provide optimal balance along the entire drive train. The assembly also cleans the exterior surface of the spray hose as it is dispensed

and collected from a driven spool or reel assembly. The reel assembly stacks the hosing in a tapered coil that is balanced to the longitudinal drive axis of the hose drive train. The hub of the reel assembly can be adjusted to accommodate different lengths and diameters of hose.

SUMMARY OF THE INVENTION

It is accordingly a primary object of the invention to provide a high-pressure tube cleaning assembly wherein a spray hose and spray nozzle can be directed at high rotational and axial rates by the assembly as the nozzle is directed through each tube being cleaned.

It is a further object of the invention to provide an assembly that includes a rotationally driven hose reel that arranges the spray hose in a fashion that avoids unbalancing the equipment relative to a longitudinal, rotational drive axis.

It is a further object of the invention to provide a hose reel having a conically tapered, hose collection hub mounted adjacent to a concentric outer cage and on which hub the hose is stacked in coils concentrically aligned to the longitudinal drive axis.

It is a further object of the invention to provide a hose cleaning assembly that cleans the hose as it is dispensed and collected.

It is a further object of the invention to provide a rotary mounted, air-controlled hose drive assembly having four polyurethane pinch-type drive wheels that axially direct the hose along the assembly's longitudinal drive axis and that is rotationally balanced relative to a hose reel.

It is a further object of the invention to provide a drive axle at the hose reel that is coupled to the hose drive assembly and from which axle a layering arm extends that aligns the hose relative to an adjustable hub at the hose reel.

It is a further object of the invention to provide a hose collection hub wherein the diameter and taper of the hose collection hub can be adjusted relative to the outer cage and center drive axle.

The foregoing objects, advantages and distinctions of the invention, among others, are obtained in the following disclosed tube cleaning assembly that has been particularly adapted for use in cleaning heat exchangers and falling tube evaporators. The invention can be adapted to other applications wherein the tool head is coupled to a high-speed, rotationally and axially directed supply conduit.

The subject tube cleaning assembly provides a mobile framework that attaches to on-site air and water supplies. The assembly includes a number of subassemblies that are concentrically aligned along a longitudinal drive axis to direct a high-pressure hose and spray head. The subassemblies are mounted to rotate in controlled synchrony at a number of pillow block bearings.

At a fore end, the hose and orifice containing spray head are directed through a hose cleaning subassembly that washes the hose with a low-pressure spray. The hose is axially directed to and fro with an air-controlled hose drive assembly. A hand-operated valve directs air to an air swivel and a pair of drive motors. Drive power is applied to a pair of driven gears and chains to follower gears attached to four polyurethane pinch wheels that abut the hose. Spring tensioners control the wheel-to-hose pressure and are able to axially direct the hose at speeds of 1 to 80 feet per minute.

The hose drive is coupled to a hose collection reel via a motor driven reel axle. A layering arm extends from the axle and directs the hose onto an adjustable hub at the reel. The hose is preferably stacked in a single layer. A swivel at the opposite end of the reel axle supplies high-pressure water in the range of 3,000 psi to 50,000 psi to the hose.

The diameter of the hub at the hose reel can adjusted relative to an outer cage. The layering arm and hub cooperate to stack the hose in concentric layers relative to the longitudinal drive axis of the assembly to assure a balanced loading. The reel, axial hose drive and hose cleaner assemblies can be operated at rotational speeds in the range of 60 rpm to 650 rpm. The assembly is thereby able to clean tubes from ½ to 6-inch diameters at rates of 1 to 80 feet per minute.

Still other objects, advantages, distinctions and constructions of the invention will become more apparent from the following description with respect to the appended drawings. Similar components and assemblies are referred to in the various drawings with similar alphanumeric reference characters. Various features of the invention may also be configured with other features in different combinations. The description should therefore not be literally construed in limitation of the invention. Rather, the invention should be interpreted within the broad scope of the further appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective drawing shown in partial cutaway and exposing the various subassemblies of the high-pressure spray cleaning equipment of the invention.

Figure 2 is a detailed perspective view to the hose cleaner and air-driven hose drive and wherein the spray head is also shown in cutaway in a typical heat exchanger tube.

Figure 3 is an enlarged plan view of the hose drive assembly

Figure 4 is a perspective view to the hose collection reel with a length of spray hose arranged on the hub and also showing length adjustable link arms and end hoops of the hub.

Figure 5 is a perspective view to the aft end of the hose reel showing the adjustable link arms and end hoops of the outer cage.

Figure 6 is a perspective view shown in partial section to an alternative hose collection reel having an outer cage and to which a number of removable upright strut plates are attached to accommodate differing hose lengths and diameters.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Figure 1 a perspective drawing is shown to the portable, high-pressure spray cleaning assembly 10 of the invention. The assembly 10 finds particular application for on-site cleaning of heat transfer tubes in commercial and industrial heat exchangers. A spray head 12 having a desired number of orifices 14, reference Figure 2, directs a number of high-pressure (e.g. 200 to 50,000 psi) streams of water against the bore walls of a heat transfer tube or pipe 16 to dislodge and wash scale and residue from the tube walls 16. The spray head 12 is rotated and axially extended and retracted from the tube 16 to most advantageously direct the spray streams from the orifices 14.

A suitable length of hose 18 is secured to the spray head 12 and is deployed and stored at a hose spool or collection reel assembly 20. The hose 18 is constructed to withstand the normal anticipated working conditions and pressures. The hose 18 is typically constructed of several layers of water impermeable material in numerous wound

wrappings and may contain wraps or bands of wire, KEVLAR and the like. The diameter of the hose 18 can be adjusted as desired (e.g. 1/8 to 1 inch) depending upon the application, diameter of tube 18 and desired working pressures.

The hose 18 is contained in a length of a flexible, tubular cover piece 22 that is secured to a hose washing assembly 24. The hose 18 is free to slide and rotate within the cover piece 22. The cover piece 22 particularly protects the hose 18 as an operator directs the assembly and hose 18 about the work site and as the hose 18 is manipulated by the operator and fitted to each tube 16 being cleaned.

A support frame 26 provides a number of wheels 28 and handles 30 that make the assembly 10 portable. Several stanchions 32, 34 and 36 rise from the frame 26 to support a number of pillow block bearings 38. A forward, hollow stub axle 40 and a partially hollow drive axle 42 are contained by the bearings 38 and permit rotation of a coupled axial hose drive assembly 44 and the hose reel 20. The horizontal spacing between and vertical offset of the stanchions 32-36 can be adjusted depending upon the size and length of hose 18 that is being deployed.

With attention to Figure 2, the hose cleaning assembly 24 extends forward of the stanchion 32 from the stub axle 40. The hose cleaning assembly 24 essentially comprises a manifold 45 having bolted cylindrical sections head and backing pieces 46 and 48 that directs several low-pressure streams of water onto the outer walls of the hose 18. A number of flow channels (not shown) are formed into head and backing pieces 46 and 48 that are secured with several fasteners 49. A fitting 50 couples a water supply line 52 to the manifold 45. The water is directed from a central bore 54 through which the hose 18

passes. One or more brushes 55 can be secured and concentrically aligned to the headpiece 46 and the hose 18 to scrub debris during hose cleaning.

The hose 18 is directed axially through the cleaning assembly 24 by the hose transport or drive assembly 44. The hose drive assembly 44 is mounted to rotate between the stanchions 32 and 34 and is covered by a safety cage 45. The hose reel 20 is mounted to rotate between the stanchions 34 and 36. Each of the assemblies 20, 24 and 44 are concentrically aligned to the center longitudinal drive axis of the assembly 10 and relative to which the hose 18 is particularly coaxially and concentrically aligned. Hose movement is thus balanced to the drive axis and the enhanced operating speeds are possible.

With attention to Figures 2 and 3, an air swivel 60 is secured to the forward end of a two-section, split drive frame 62 of the drive assembly 44. The frame assembly 62 supports four polyurethane pinch-wheels 64 that grip the hose 18. Adjusting bolts 66 and springs 68 control the tension or pinch pressure of the wheels 64 against the hose 18. Two pairs of the pinch-wheels 64 (only two of which are shown) are arranged 180° opposite each other to overly each other. The wheels 64 can also be positioned in other arrangements. The wheel material can also be varied as desired relative to the hose 18 to provide optimal friction and wear tolerance between the wheels 64 and hose 18.

A hand-operated valve 70 controls airflow from an air supply 69 through the swivel 60 and to a pair of air driven motors 72 secured to the frame 62. A drive axle 74 of each motor 72 is coupled to a drive gear 76. Power is directed via a chain 78 to a pair of follower gears 80 that are coupled to axles 82 that are secured to each drive wheel 64. The valve 70 is controlled to bi-directionally direct the hose 18 with a reciprocating motion at a desired axial speed to achieve proper tube cleaning, hose deployment and

collection. A coupler 84 at the aft end of the frame 62 secures the frame 62 to the drive axle 42. Although an air powered transport drive is presently used, hydraulic, electric or other types of power drives can be adapted to the assembly 44.

The rate of movement of the hose 18 through the hose drive assembly 44 is regulated in relation to the rotational speed of the reel 20 to assure that the hose 18 is synchronously extracted and stacked to avoid kinking, strain or slack at the reel 20. The relative speeds also take into account the operating rigidity of the hose 18, which is relatively stiff when placed under the pressures discussed herein. Any of the latter conditions can unbalance the assembly 10. During a cleaning stroke, when the hose 18 is extended into a tube 16, the assembly 44 and reel 20 rotate at a slower speed. During hose retraction from the cleaned tube 16, when there is relatively little resistance to motion, the assembly 44 and reel 20 are rotated faster. The operator via the valve 70 manually controls the relative rates of rotation.

The relative rates are established empirically as required to meet the working conditions by regulating the air pressure at the valve 70 in relation to the constant drive power provided to the reel 20. An electric motor and V-belt/pulley transmission determine the rotational speed of the reel 20 which are discussed in more detail below. A variety of automatic control assemblies can also be adapted to the assembly 10 to obtain automatic speed regulation, such as by monitoring the condition of the hose 18 at the reel 20 via appropriate sensors. Sensor feedback can be directed to the speed regulators at the assembly 44 and reel 20.

For jobs requiring multiple assemblies 10, cleaning time can be reduced and equipment operation improved by coupling the several assemblies 10 to the single air

supply 69 and operating the assemblies 10 in complementary fashion. That is, as the hose 18 of one assembly 10 is directed in a cleaning stroke, the hose 18 of another assembly 10 is collected. The demand on the air supply is therefore substantially continuous.

With attention to Figure 4, the hose 18 passes through a bore 86 at the forward end of the drive axle 42 and a bore 88 of a layering arm 90 that extends from the side of the axle 42. The layering arm 90 directs the hose 18 onto a center hub 92 of the reel 20. The hub 92 is concentrically positioned relative to an outer cage 94 such that the hose 18 is deposited in a single, layered coil that is concentric to the drive axis of the assembly 10. The changing weight of the hose 18 and contained liquid is thus dynamically balanced to the assembly 10. The reel assembly 20 can also be constructed to provide for multiple side-by-side coil wraps. For example, the diameter of the hub 92 may be constructed to expand and contract dynamically via centrifugal force and/or automatically with a controlled linkage. The arm 90 can also be mounted to pivot relative to the hub 92 to control layering. In the latter regard, the arm 90 can be hinged to pivot at the axle 42 and the linkage arm 93 can be constructed in two telescoping sections 89, 91.

Figure 4 also depicts adjustment features of the reel assembly 20. That is, the fore and aft diameters of the hub 92 can be adjusted at the interconnected, telescoping hoop pieces 96, 97 and length adjustable spoke pieces 98, 99. Proper adjustment of the hub 92 can be arranged to be cylindrical or provide a taper. The hub 92 is presently constructed to taper inward as it extends forward and accommodates a single, stacked coil of hose 18.

The hoops 96, 97 and spoke pieces 98, 99 are adjusted in concert with a number of fasteners 100. Slots 102 in the spoke pieces 98, 99 overlap the fasteners 100. The outer cage 94 can also be constructed with adjustable hoops 101, 103 and spoke pieces

104, 105 relative to slots 102 and fasteners 100 as shown by representative example at Figures 4 and 5. Still other adjustable arrangements at the layering arm 90 and hub 92 can be provided to balance multiple coils, yet maintain a concentric assembly.

Figure 5 depicts a drive pulley 110 that is secured to the aft end of drive axle 42. Rotational drive power is supplied to the axle 42 from another pulley attached to via a drive motor 114 and belt 116. The rotational speed can be varied as desired by adjusting the relative diameters of the motor pulley to the drive pulley 110. The assembly 10 has been operated at speeds in excess of 400 rpm and approaching 650 rpm without experiencing vibration. This is in contrast to maximum operating speeds of 60 rpm for competitive assemblies.

A bore 118 at the aft end of the drive axle 42 is coupled to a swivel 120 and a high-pressure water source 121. Water is directed through the swivel 120, axle 42, a stub pipe 122 and coupler 124 to the hose 18. The working spray pressures can be varied as desired. Presently, pressures in the range of 4,000 psi to 36,000 psi are preferred when cleaning tubes found in boilers and evaporators.

Figure 6 discloses an alternative reel assembly 120 that can be adjusted with relative ease to accommodate hoses 16 of different diameter and length. The reel assembly 120 provides a base 122 that is defined by a number of annular bands 124 and a center collar piece126 that mounts to the axle 42. A number of inner and outer cage bands 127 and 128 are vertically offset from the base 122. The base and cage bands 124, 126 and 128 are coupled (e.g. welded) to a number of upright, planar strut plates 130 at notches 132 let into the peripheral edges of the plates 130.

Only one strut plate 130 is shown, but it is to be appreciated that several other identical plates 130 are mounted to align with notches 134 at each of the bands 124 and mate with the bands 124, 127 and 128. The assembly 120 provides for eight plates 130, but the number of plates 130 can be varied as desired.

A hose collection channel 136 is defined at each plate 130 between an outer arm 134 and inner hub 140. A number of coils of the hose 18 are shown as they appear when layered in the channel 136. The channels 136 project at an acute angle relative to the base 122 as they extend inward toward the collar 126 to define a tapered hose storage space.

The assembly 120 can be constructed of a variety of materials, although aluminum is presently preferred to reduce weight. Weight relief holes 142 are also provided in the plates 130.

The channel 136 is constructed oversized to nominally accommodate hoses from ¼ to 2-inch diameters. When a smaller diameter hose 18 is being used, a frustum shaped spacer 144 is also mounted in the channel to take-up space and assure the hose is layered in uniform coils.

The strut plates 130 thus define several vertical ribs that collectively capture and contain the hose 18 in relation to the layering arm 90. The reel assembly 120 can be adapted to accommodate hoses 16 of different diameter and length upon attaching an appropriate spacer 144.

While the invention has been described with respect to several assemblies and considered improvements or alternatives thereto, still other constructions may be suggested to those skilled in the art. For example, the hose washing assembly 24, axial drive assembly 40 and/or adjustable reel assembly 20 can be used in combination or can

be provided in other cleaning system arrangements. The cleaning equipment can include other controls for adjusting the rotational and axial operating speeds. Sundry safety controls can also be provided. The foregoing description should therefore not be literally construed and should instead be construed to include all those embodiments within the spirit and scope of the following claims.

What is claimed is: